ICCPGE 2016, 1, 25 - 30

Petrographic Analysis of the Sarir Sandstone in Messla Oil Field, Southeast Sirte Basin, North Central Libya

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Abstract

Petrographic studies show that the Sarir sandstone in composition from (sub-arkose to arkosic arenite). During early diagenesis, the Sarir sandstones were modified by calcite, dolomite, and locally pyrite, diagenesis process; replacements of corroded silica by carbonates. Cementation fluvial sandstones Intrastratal dissolution and precipitation of kaolinite in the resulting pore space. Deformation of micas between more resistant grainy pre-dates one phase of quartz overgrowth, probably the carbonates. The methodology was conducted with the review of the previous; published papers, the open file of the Arabian Gulf Oil Company (AGOCO). Thin sections were used for the petrographic analysis with polarized and scanning electron microscopes (SEM). The results of the study were: subsurface investigations including cores (conventional and side walls), petrographic analysis, and wire-line logs suggested that this formation (Sarir sandstone) can be divided in to three main units in Messla oil field. The quarzitic sandstones of (the lower and the upper Sarir sandstones) are considered to be the main producing horizons where quartz grains have undergone a complex diagenetic history, including: authigenesis, quartz and feldspar overgrowths, dissolution, carbonates cementation, and replacement. The nature of the shale facies, (i.e. lack of organic content, and presence of oxidizing conditions indicated by iron oxides color, indicate that they are not a significant source of hydrocarbons. On the other hand, the Rakb shale is the only source rock in the studied and adjacent areas.

Keywords: Petrography; exploration; chemical; petroleum; gas; conference

1. Introduction

Sarir sandstone cover a large area of Sirt basin. This sequence forms two regressive phases. This study of the Petrographic Analysis of the Sarir Sandstone in the Messla Oil Field is a follow up and expansion of what has been done on the geology of this area at the Arabian Gulf Oil Company (AGOCO) exploration department and the few papers that dealt with the geology of the region in general since. In the study area the Sarir section consist of three units; they are the Lower Sarir Sandstone, the Red shale, and the Upper Sarir Sandstone [1] . Although, the stratigraphic aspects of the Sarir Sandstone have been fairly studied, its Petrographic Analysis have not been covered. Accordingly, this study was devoted mainly to the Petrographic Analysis of the Sarir Sandstone in the Messla Oil Field. This study was performed with three main goals; first: to study in details the Petrographic Analysis of these important sandstone units, second this work, hopefully, will be a contribution to the geology of the area, and third to provide a case study for any similar examples in the natural resources exploration. The Messla Oil Field is located in the southeastern portion of the Sirt Basin, north central Libya, approximately 500 Km Southeast of Benghazi and 40 Km Northwest of the Sarir Oil

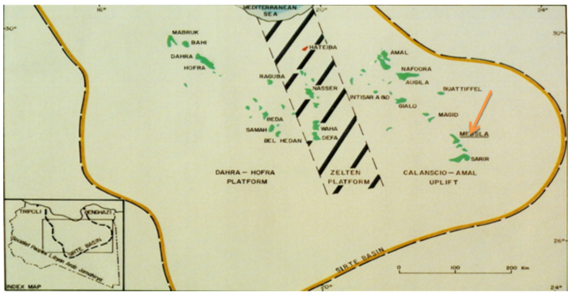

Figure 1.1: Color] Index map of Sirt basin oil fields (after Clifford, et al., 1980).

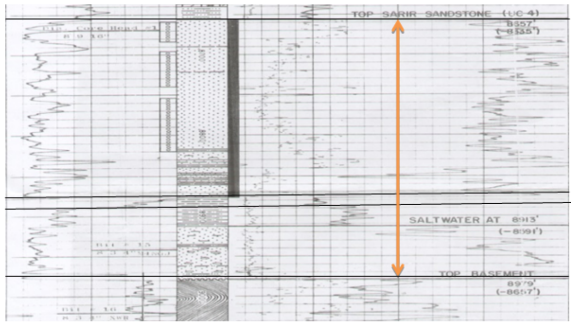

Figure 1.2: Composite Log; Sarir Succession (orange arrow).

Field Figures 1.1. This Study focus on Petrographic Analysis of the Sarir sandstone in Messla oil field, which mostly occur in Southeastern Sirt basin. This conducted reviewing of the previous work in Messla Oil Field; published papers, the open file of the Arabian Gulf Oil Company (AGOCO), for the data to be used in Petrographic Analysis. Four cored wells (DD25-80, HH1-65, HH3-65 and L5-65). 418 feet of conventional and side wall cores were used for the core descriptions and cut samples. (130) thin sections that represent the Sarir Sandstone Units were used for the Petrographic and scanning electron microscopes (SEM) analysis. This method was implemented in AGOCO, Benghazi except SEM analysis which was done in the Industrial Research Center (IRC) Tripoli. Also, drawings, typing, computer works, zerox, etc. were done in Misurata. The Messla Oil Field was discovered in 1971 by a wildcat HH1-65. This well was located on a seismically controlled southeasterly plunging nose upon the concept that the Lower Cretaceous Sarir Sandstone, productive in the L-Field wedged out towards the west and the northwest against Messla bald basement [1]. HH1-65 penetrated 366 feet of Sarir Sequence in the interval 8760-9126, and potential tested at the rate of 10,900 barrels per day of 38 degrees API oil [1] .

2. Material and Methods

2.1. Core Descriptions

Cores from four wells (DD25-80, HH1-65, HH3-65, and L5-65) have been described for this study. These are evenly distributed across the field and cover all stratigraphic units (Upper and Lower Sarir Sands with Red Shale). A series of core photographs was taken during core description work to capture the typical appearance of the rocks and results were recorded on cores sheets.

2.2. Sarir Sandstone

The sediments of the Sarir Group represent the first depositional cycle of the incipient-rift sequence. Age dating of the sequence is often difficult or not possible due to the lack of fossils or is hampered by the occurrence of reworked fossils from older Palaeozoic or Mesozoic strata [2]. Many different facies associations and depositional environments have been interpreted for the Sarir Group by different authors. Depositional environments are predominantly fluvial, ranging from alluvial fans, braided rivers and meandering streams to marginal marine, coastal plain and lacustrine [3] . The Upper Cretaceous succession in the area of the Messla field contains marine anhydritic shales, shales of various colours and limestones representing the Rakb Formation. The most productive source rocks included within the Upper Cretaceous are the ‘Sirt Shales’ and ‘Rakb Shales’ of the Sirt Basin [3]. The Sirt Shale (Upper Cretaceous, Campanian/Turonian) is considered to be the dominant source rock in the Sirt Basin petroleum province [4]. The thickness of the Sirt Shale ranges from a few hundred feet to more than 2500 feet in the troughs. These rocks are within the oil-generating window below 8100 feet in the central and eastern Sirt Basin [5] . Gras and Thusu assume that the Upper Cretaceous Rakb Shale, containing kerogen types 1 and 2, is the principal and widespread source rock. The mixture of marine algal and terrestrial organic mat-

ter was deposited under restricted conditions in an intra-shelf basin [3].

3. Results and Discussion

3.1. Petrographic Analysis

Thin sections were prepared in order to make the open hole space visible. The modal composition (i.e. various detrital components, matrix, and cement) was evaluated microscopically. Further differentiation was made between carbonate cement, anhydrite cement, clay cement, and open pore space. Quartz is the most abundant framework component. Chloritized phyletic lithoclasts are the most conspicuous rock fragments in Sarir sandstones. Other common rock fragments include Chert, quartzite, dolomite, hematinic siltstone, and chalcedony. Sarir siliciclastic are barren of fossils. (Ref.[3] reported Late Jurassic-Early Cretaceous ages for plant fossils in Sarir cores.

3.2. Petrographic Analysis of the Lower Sarir Sandstone

The petrographic analysis of the Lower Sarir Sandstone started by studying the thin section that was undertaken from the conglomeratic section of the Lower Sarir Sandstone which unconformably overlies basement. The main component of the following slides is quartz grains, which is monocrystalline partly corroded and with silica overgrowths (Fig. 3.1 and Fig. 3.2). These figures (3.1&3.2) illustrate an authigenic overgrowth (O) on a detrital quartz grains (Q) and shows high preserved primary interparticle porosity (P) (blue stain); the pore spaces are partially filled with black material (HO) i.e. heavy oil. This rock type has an excellent porosity, i.e. providing a good reservoir rock. In the Lower Sarir Sandstone the thin section (Fig. 3.3) illustrates the clay minerals, mainly kaolinite (k), and partly filling the pore spaces. It also illustrates the sandstone, which is medium to coarse grained, subangular to subrounded, clayey in the lower half of the thin section. A few grains of K-feldspar (F) are present; they are partially altered to kaolinite (K) as it appears on the right lower corner of the thin section.

Thin section from the upper part of the conglomeratic section in the Lower Sarir

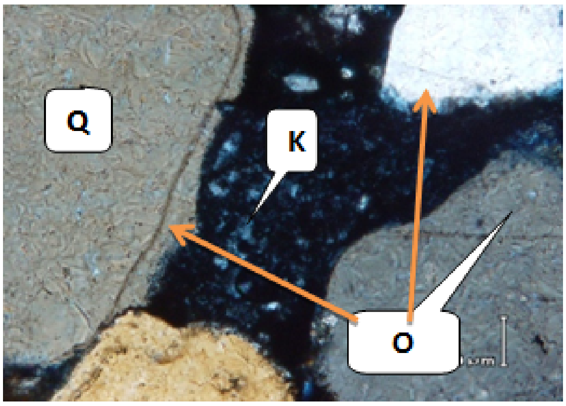

Figure 3.1: Showing an- authigenic & corroded overgrowth (O) on detrital quartz grains (Q), Kaolinite (K).

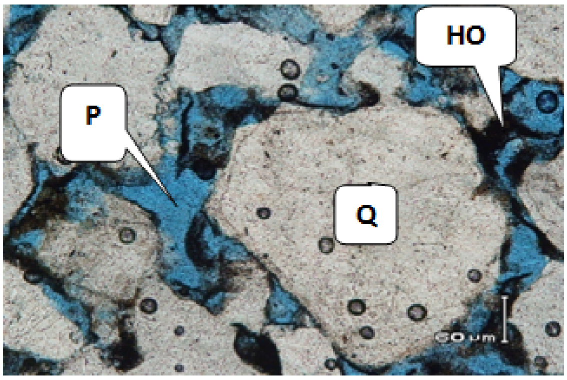

Figure 3.2: Shows high preserved primary interparticle porosity (P), and Heavy Oil (HO) between quartz grains.

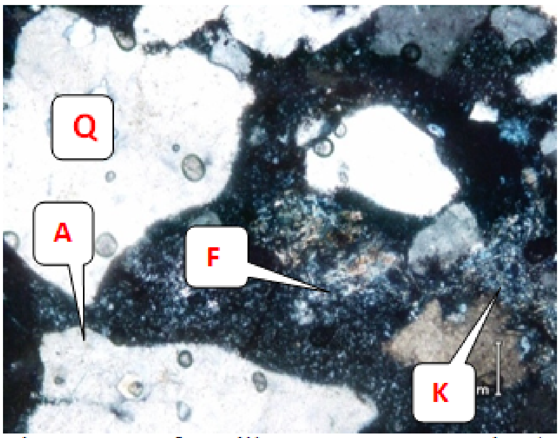

Figure 3.3: Illustrate quartz grains (Q), angular grains (A), Kaolinite (k), and Feldspar (F).

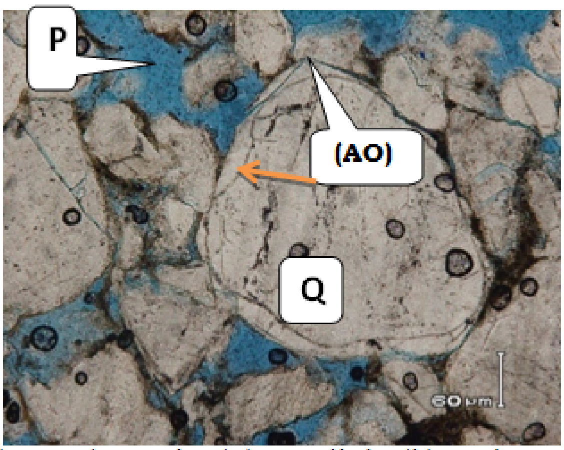

Figure 3.4: Shows overgrowth (AO) and porosity (P).

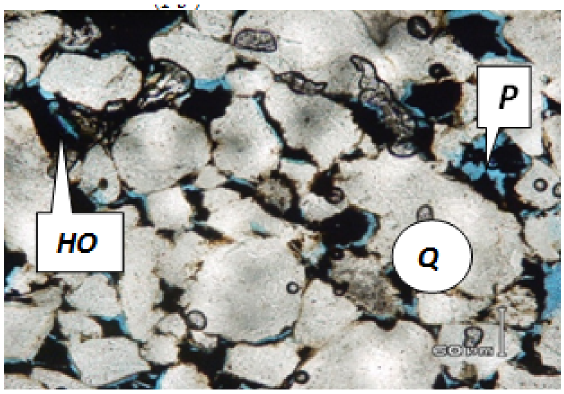

Figure 3.5: Illustrates slightly silty and clayey, fairly porous, and with hydrocarbon accumulations (black color heavy oil)(HO).

Sandstone shows that it consists mainly of poorly sorted silty quartzitic sandstone (Figure 3.4). The detrital grains, which mostly monocrystalline quartz (Q), are bimodal ranging from silt to medium grained sand size. Grains of the coarse fraction are subrounded and some of them with silica overgrowth (AO). The finer and elongated, apparently subangular to angular, and with irregular surfaces.

3.3. Petrographic Analysis of the Upper Sarir Sandstone

The Upper Sarir Sandstone is overlying the Red Shale and starts with sandstone, which consists of fine to medium grained, angular to subangular and subrounded monocrystalline quartz grains; it is slightly silty and clayey, fairly porous, and with hydrocarbon accumulations (black color heavy oil) (HO) The above mentioned sandstone unit is fining upward and grading to siltstone, with the main constituents are angular-subangular, elongated detrital quartz grains, and with intergranular porosity (P), and oil stains (HO) (Figure 3.5). The upper part of the Upper Sarir Sandstone consists of fine –medium, rounded to well rounded, microcrystalline quartz grains (Figure 3.6). Disseminated Pyrite and marcasite (py) seem to have invaded the rock during late diagenesis Fig.3.7.

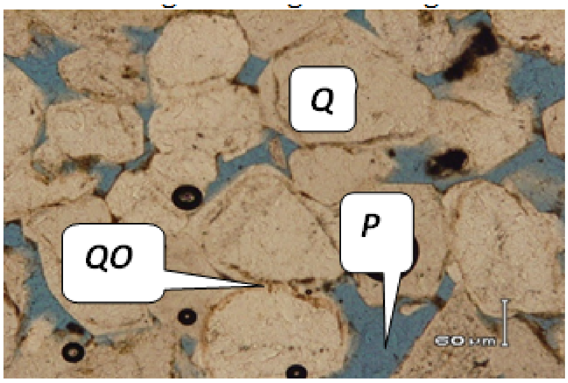

Figure 3.6: An authigenic overgrowth (O) , and well distributed open pore spaces (P).

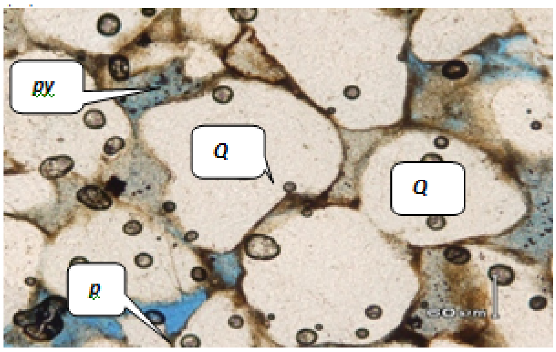

Figure 3.7: Photomicrograph of thin section to illustrate another unit of brownish hydrocarbons stain. The pore space (P) on the upper the Upper Sarir Sandstone, quartz grains (Q), porous quartz arenites with left side of the slide is partially filled with disseminated pyrite (py).

3.4. Diagenesis

Sarir sandstones have undergone a complex diagenetic history. The complete diagenetic sequence is not present in individual samples, but has been

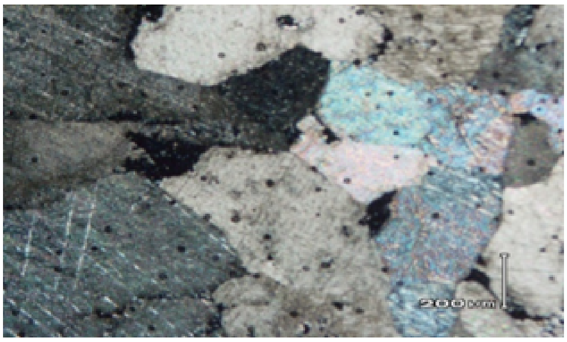

Figure 3.8: Illustrates Well-developed anhydrite crystals.

established through petrographic and SEM analyses of all available thin sections.

3.5. Chlorite

Authigenic chlorite is the dominant clay mineral in Sarir sandstones. Two distinct episodes of chlorite precipitation are evident: early cements and a late replace phase. Cement-stratigraphic relationships show that precipitation of pore-lining chlorite rims is the earliest diagenetic event.

3.6. Quartz and Feldspar Overgrowths

Quartz and K-feldspar overgrowths; these cements appear to be lacking in the interstratified chlorite-cemented sublitharenites.

3.7. Early Carbonate/Anhydrite Cements

The dominant authigenic carbonate minerals in Sarir sandstones are nonferrous calcite and nonferrous dolomite. These sparry carbonate cements are commonly superimposed on early chlorite rim cements; calcite is more abundant than dolomite. Where early calcite and dolomite cements are pervasive, they occur to the exclusion of pore-filling chlorite (Figure 3.9 & 3.10).

3.8. Dissolution/Kaolinite Cementation

Using the textural criteria most of porosities have been interpreted as secondary. These secondary pores resulted from partial to complete dissolution of quartz (Q) and detrital feldspar alteration to kaolinite.

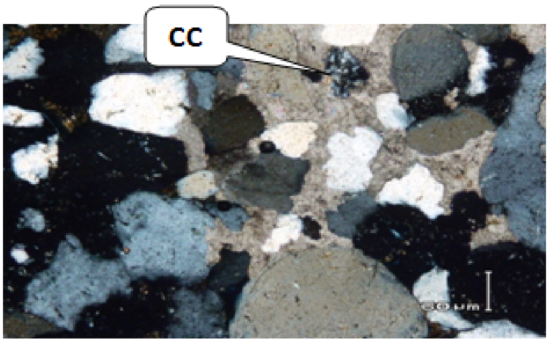

Figure 3.9: Illustrates Poikilotopic calcite cements (CC).

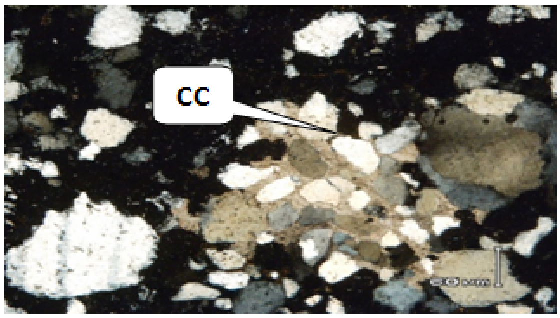

Figure 3.10: Illustrates sandstone diagenetic texture. Poikilotopic calcite cements (CC) in which the carbonate crystals completely enclose several quarts grains (Q).

3.9. Scanning Electron Microscope Analysis (SEM)

SEM results are in line with the observations made during thin section analysis. Kaolinite is the most abundant clay mineral filling the pore space. The Kaolinite cement is often attached to the quartz overgrowth that can be observed on most of the detrital quartz grains after feldspar alteration.

3.10. Ferroan Calcite/Ferroan Dolomite

Late ferroan carbonates occur as cements and replacement phases. These late ferroan carbonates occur as cements in secondary pores created by dissolution of detrital feldspars and, more commonly, as sparry crystals that replace detrital grains e.g. corroded quartz overgrowth. Mechanical compaction influenced Sarir siliciclastic throughout much of their burial history; evidence of chemical compaction is relatively minor. Emplacement of hydrocarbons occurred early.

3.11. Reservoir Properties

Petrographic and SEM analysis demonstrate that a series of early cementation and compaction events, in combination with late burial diagenesis, have occluded most of the porosity in these sandstones. Early chlorite rims, pore-filling chlorite, calcite, dolomite, and anhydrite cements have pervaded the primary pore network. Bitumen coatings on chlorite rim cements record an early episode of oil migration. Consequently, most diagenesis postdated oil migration. Sublitharenites containing rock fragments have the highest frequency of chlorite cement. This suggests that rock fragments sourced the iron and magnesium for the authigenic chlorites in Sarir sandstones. Following precipitation of chlorite and pervasive cementation by non-Ferroan carbonates and anhydrite, the influx of corrosive fluids created secondary porosity by partial to complete dissolution of labile framework grains and intergranular cements. These secondary pores have been cemented with kaolinite and later Ferroan carbonates. Hence, this dissolution event did not improve reservoir character. Late burial diagenesis of Sarir siliciclastic, by analogy with other Gulf of Sirt basin formations, occurred at elevated temperatures (100° to 150°C) based on the presence of abundant detrital feldspars. The pervasive distribution of late pyrite in some Sarir Formation cores provides evidence of thermochemical sulfate reduction. The Sarir Formation diagenetic system is inferred to have been semi-closed because components needed for the formation of several diagenetic phases.

4. Conclusion

The nature of the sandstone facies provided reasonable reservoir rocks. The Red Shale member represents a well-developed break between the two Sarir Sandstone members; it also provides a good seal for the underlying sandstone of the Lower Sarir Sandstone. The nature of the shale facies, (i.e. lack of organic content, and presence of oxidizing conditions indicated by iron oxides color), indicate that they are not a significant source of hydrocarbons. Diagenetic alteration of rock fragments, detrital feldspars, and authigenic anhydrite liberated ions that re-precipitated in situ as cements. However, the sodium required for albitization, as well as the calcium and magnesium needed for precipitation of pervasive carbonate cements, most probably had an extra formational source. In a general since, an example of petroleum producing fluvial deposits. This study, hopefully, enhances the understanding of the nature of the rock sequence in an important giant oil field. It is a contribution to the geology of the region; and it can be of great help in the exploration of similar examples locally around the Messla high and regionally. Although, this study reasonably covered the Sarir Sequence in the Messla Oil Field, further follow-up study, that covers more wells and expands to adjacent areas, will be very useful.

Acknowledgment

The authors gratefully acknowledge the financial support given for this work by the Al-Mergib University, Conference Committees, sponsors, and all others who gave a help in order to success.

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